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PRACTICAL WORK ON THE NOISE ATTENUATION WITH EXHAUST AFTER TREATMENT SYSTEMS ON A ST4A SCOOPTRAM IN STRATHCONA MINE, FALCONBRIDGE LTD.

M.U. SAVICH AND J.K. VEGLO

ELLIOT LAKE LABORATORY

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by

M.U. Savich* and J.K. Weglo**

ABSTRACT

The measurement and evaluation of the noise emanating from a ST4A scooptram in an underground stope under a simulated work cycle, and under three conditions of after treatment systems is covered:

These were:

a) bare engine,

b) an in-line small filter compared to a larger filter,

c) the larger filter with an in-line muffler in series with a fume diluter.

The results showed an attenuation of the scooptram at work of 8 to 15 dBA, 16 cm from the exhaust pipe of the machine, to 4.8 dBA at the operator's ear. Recommendations are made to increase the attenuation at the operator's ear by additional improvement in design of the fume diluter.

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TRAVAUX PRATIQUES SUR LA RÉDUCTION DU BRUIT PAR LA MODIFICATION DU SYSTÈME D'ÉCHAPPEMENT DE LA CHARGEUSE À PELLE ST4A À LA MINE STRATHCONA DE LA FALCONBRIDGE LTD.

par

M.U. Savich* et J.K. Weglo**

RÉSUMÉ

Le résumé porte sur l'évaluation et les mesures du bruit produit par le système d'échappement de la chargeuse à pelle ST4A dans des conditions de travail simulées dans un chantier d'abattage souterrain. Afin de déterminer le niveau de bruit, on a modifié le système d'échappement de trois façons soit:

a) le moteur à découvert
b) l'utilisation d'un petit filtre pour établir la différence avec l'utilisation d'un grand filtre
c) l'alignement d'un grand filtre, d'un silencieux et d'un dilueur de gaz d'échappement

Les résultats ont montré une réduction du bruit provenant du véhicule en marche de 8 à 15 dBA à une distance de 16 cm du tuyau d'échappement, et de 4,8 dBA au niveau de l'oreille de l'opérateur. On recommande d'améliorer la conception du dilueur de gaz d'échappement afin d'atténuer le bruit au niveau de l'oreille de l'opérateur.

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INTRODUCTION

In current mining operations the diesel engine provides a safe, efficient, and highly mobile source of power. In the major underground mines in Canada the most common types of diesel equipment are load-haul-dump (LHD) machines and ore trucks. In general, there is a tendency to use high-horsepower diesel LHD machines in mines to achieve maximum productivity. The increased use of diesel powered equipmmet in underground mines has not shown any cause for concern if the engine is adequately maintained.

This research and development of an exhaust filter and fume diluter combination on a ST4A scooptram in an underground stope at the Strathcona Mine was performed to determine the improvement on the working environment of after treatment systems. Laboratory work had indicated that a reduction of 50 to 80% of particulate matter and more than 90% of hydrocarbons could be expected.

The intent was to capture particulate matter on the filter and allow it to burn off at the normal operating temperature of the engine into less toxic compounds based on measurement by the Ames Test. Since the metal filter was designed with platinum as a catalyst to allow burnoff at engine temperature it might be expected to oxidize some NO_x to NO_2. The fume diluter was added in series for two reasons. The first was to air-quench the engine exhaust to prevent NO_x oxidizing to NO_2. The second was to throw any exhaust fumes away from the operator into the main stope ventilation system. The latter would also provide clean air to the engine to prevent clogging of the filter.

Since the filter was in-line on the exhaust, it could also be expected to attenuate noise from this source. This report presents the measurement of the noise and evaluation of these results.

LOAD-HAUL-DUMP MACHINE

A load-haul-dump (LHD) is the noisiest machine in terms of operator noise exposure. Noise sources of LHD machines are (1):

- engine airborne noise from the engine or block structure;
- engine structure-borne noise caused by engine vibrations throughout the machine's structure;
- auxiliary-component noise from the transmission and hydraulic system;
- fan noise;
- exhaust noise;
- air intake noise from the intake and structural radiation from intake piping.

At the component source levels, the highest levels are produced by engine and exhaust outlet noise. Levels of these two sources were measured. Octave band frequency levels were measured on both sides of the motor, and A-weighted sound pressure levels were measured at the exhaust and outlet pipe. Also, while measuring the octave band and A-weighted sound pressure levels, the operator's position was taken into consideration since total machine noise was being measured with a view to its eventual reduction.

Tests were performed in the Strathcona Mine at Stope 23-E2-E4 (Fig. 1). The stope was narrowed by using a plastic curtain which had a length of 43 m (140 ft), a width of 15.25 m (50 ft), and a height of 3 to 5 m (10 to 16.5 ft). The stope was narrowed to create a regular ventilation current, thus facilitating analyses of gases emitted by the Wagner ST4A Scooptram (No. 41). The No. 41 scooptram has a 145 hp engine and had been used for 3,276 hours of operation since it started service on August 22nd, 1979. Because of different absorption characteristics and shapes of walls, noise reflection was not always the same. The test program had two objectives:

1. To determine what noise levels the Wagner ST4A scooptram produced at the

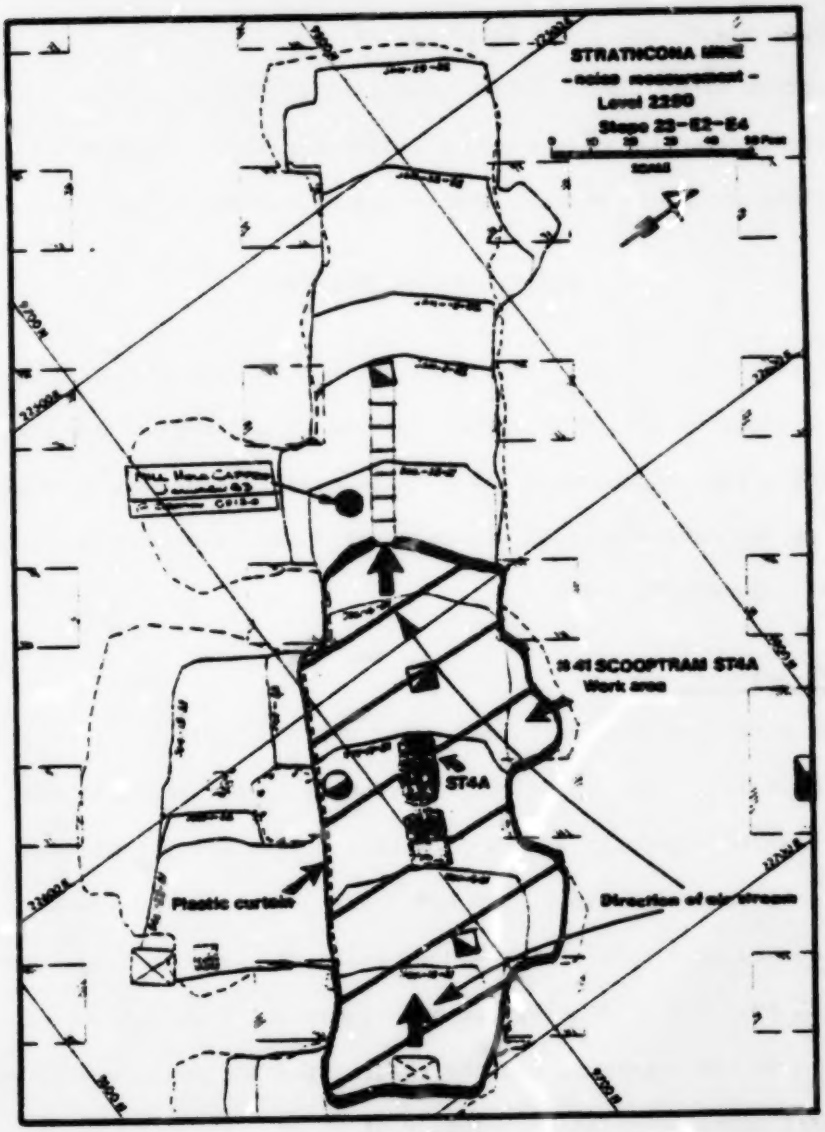

Fig. 1 - The test centre of Wagner ST4A scooptram in the Strathcona Mine.

exhaust outlet, and the levels of operator's exposure to this noise under three conditions (Fig. 2):

- scooptram without muffler or filter,
- scooptram with small and large filter,
- scooptram with filter, muffler and fume diluter.

2. To characterize the noise produced under the three above mentioned conditions and to recommend improvement of, or means for their control.

RESULTS OF MEASUREMENTS

Measurement results are presented in the noise spectrum in octave bands for a distance of 1 m from the left and right sides of the motor and for the operator's ear (Appendix A, 1-4). Also noise measurements in dBA were performed at the exhaust outlet and operator's ear, and each were then averaged over 1 min (Appendix B, 1-6).

OCTAVE BAND ANALYSIS

Measurements were performed using a Sound Level Meter which conforms with ANSI S1.4-1971 Type 1. Noise measurements in octave bands yielded the following results (Appendix A, 1-4): with the ST4A scooptram, spectrum differences between IDLE and W.O.T.* noise are well marked. However, an exception occurs at 31.5 Hz. The W.O.T. state of the engine has a high noise level at 125 Hz. The ST4A scooptram has almost equal values between filter 1 and filter 2 on the spectrum, and the results for the two are very similar. In both cases peaks occur at a frequency of 63 Hz. These peaks do not have a marked influence on overall noise in the A-network. In the case of the scooptram with filter, muffler and fume diluter two peaks occur: one from the fume diluter at its outlet, and the other at the operator's ear at a frequency of 125 Hz (most probably from the fume diluter inlet, Apendix A-4). Neither of

*W.O.T. = Wide Open Throttle.

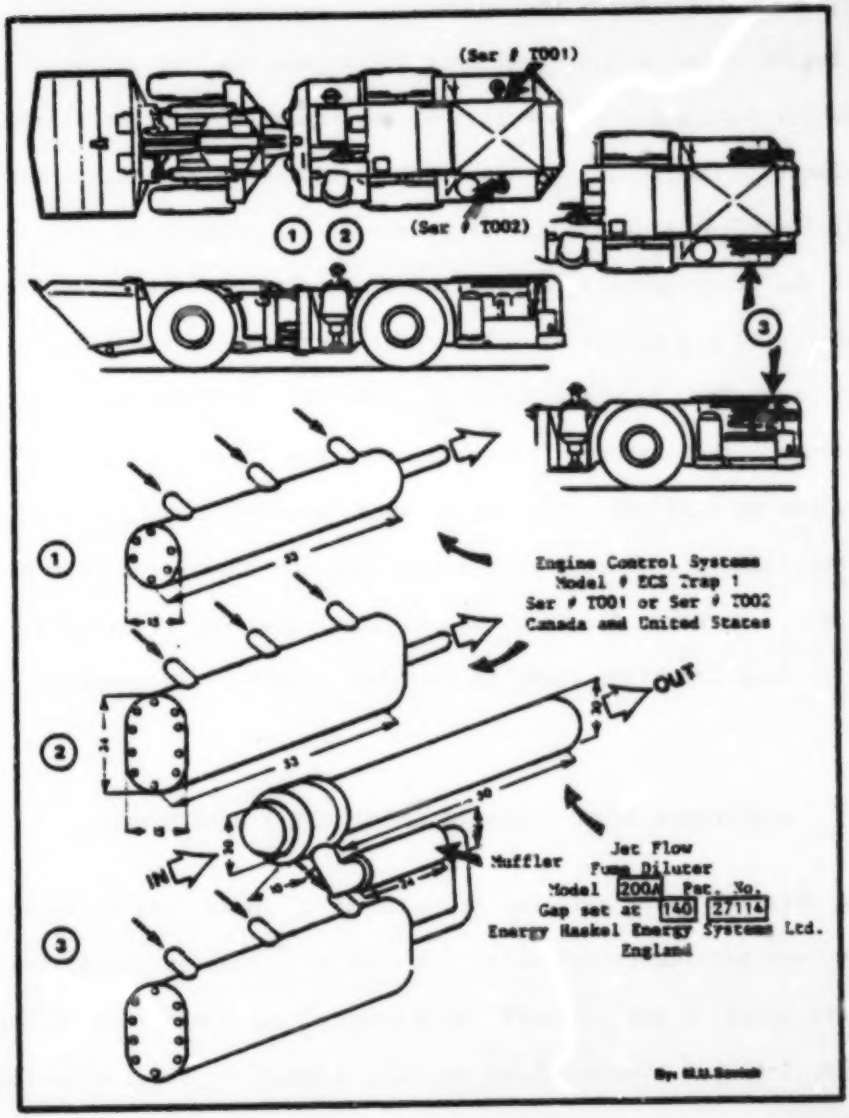

Fig. 2 - Exhaust treatment during tests:
1. Small filter, 2. Large filter,
3. Filter, muffler and fume diluter.

these two peaks has a marked influence on the A-network. This noise at the operator's ear can be reduced with deflectors mounted at the diluter's inlet to deflect the noise towards the outlet.

Engine noise at W.O.T. without filter has the highest level of noise, 110.12 dBA for both sides (Table 1). Filter, muffler and fume diluter decrease engine noise by 8 dBA to 102.25 dBA. The exception is the engine with filter 2 alone at its right side. Noise increases at the right hand side are likely because of the heterogenous* metal filter. Despite mounting a muffler and fume diluter, with the engine at idle, noise increases by 3.75 dBA at the operator's ear. This is understandable since the diluter's inlet points directly towards the operator. However, when the engine is at W.O.T. state, noise is lower by 4.25 dBA. This difference from IDLE to W.O.T. requires further investigation. During this test, impulse, impact and peak noise were also measured. In Table 2 it can be seen that relations are similar to those in Table 1. Left and right sides of the engine both yield the same or similar results.

A-WEIGHTED SOUND PRESSURE LEVEL (SPL_s) MEASUREMENT

A detailed level and time study, using a sample rate of 4/sec averaged over 1 min, may provide enough data to arrive at a statistical distribution or time history graph in the computer, with a very high confidence in results (Appendix B, 1-6). S. Bandopadhyad and R.V. Ramani, in their analysis of diesel exhaust dispersions in underground airways have adopted the method of averaging over 1 min as being the best one (2). A-weighted sound pressure levels were measured with Type 2 instruments, complying with ANSI S1.4 - 1971.

In this test, exhaust noise at both sides of the motor and total noise

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* Metal filters pressed in the shop for R & D work and not for a normal production run.

Table 1 - Noise levels in A-weighted network of ST4A scooptram under different testing conditions.

Condition of Test	Engine Status	Noise in dBA							
		Scooptram (Distance 1 m)						Operator	
		Left Side		Right Side		Both Sides			
		Meas'd	Est'd	Meas'd	Est'd	Meas'd	Est'd	Meas'd	Est'd
Without Filter	Idle	90.75	90.6	91	91.4	90.87	91	83.75	84.2
	W.O.T.	112.25	112.7	108	108.7	110.12	110.7	101.75	101.8
With Filter-1	Idle	88.5	88.9	88.5	88.7	88.5	88.8	81	81.2
	W.O.T.	104.25	104.6	103.25	103.4	103.75	104	96.5	96.1
With Filter-2	Idle	87.5	87.7	88	89	87.75	88.35	82	81.9
	W.O.T.	103.5	104.3	105	105.1	104.25	104.65	97	97.4
With Filter Muffler and Fume Diluter	Idle	86	86.4	87	87.6	86.5	87	87.5	87.2
	W.O.T.	102	102.2	102.5	102.6	102.25	102.4	97.5	97.4

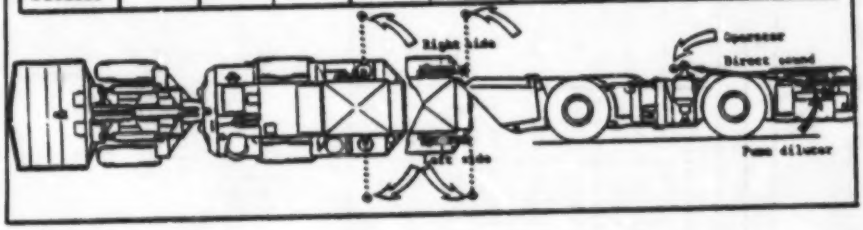
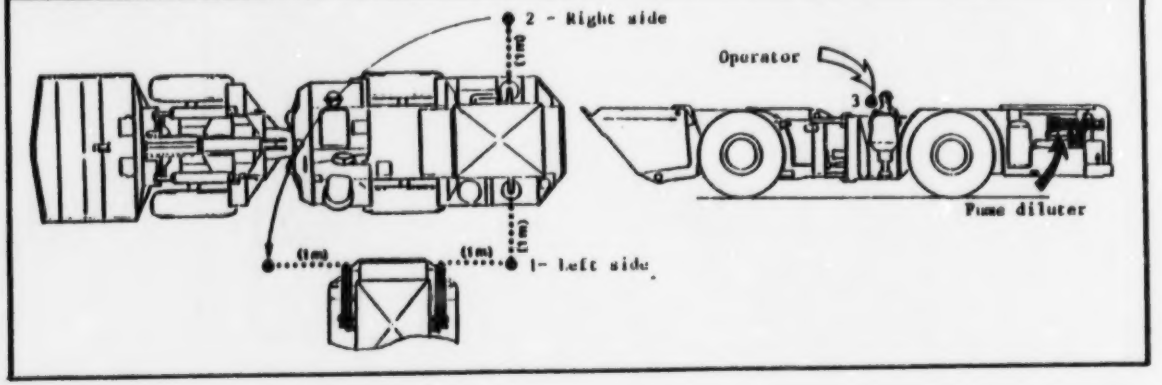


Table 2 - The noise data: impulse, impact hold and peak hold at left and right side, exhaust outlets and the operator's ear during octave band measurement.

Engine Status	Position	Level in dB											
		Condition of Test											
		Without Filter			With Filter-1			Wich Filter-2			With Filter, Muffler and Fume Diluter		
		Impulse	Impact Hold	Peak Hold	Impulse	Impact Hold	Peak Hold	Impulse	Impact Hold	Peak Hold	Impulse	Impact Hold	Peak Hold
Idle	1	92.5	93.5	106.75	89	90.5	103.25	88.5	89.7	102	88	89	101
	2	92	92.5	105.5	89	90.25	103.25	90	91	102.5	87	87.5	100
	3	84.5	86	96.75	81.5	83	94.75	83	88.5	95.5	83	84	96
W.O.T.	1	112.25	113	124.5	104.5	105.5	117	104	104.5	117	103.5	103.5	115
	2	108.75	109.75	121.5	103.5	104.5	116.25	105.5	106	118.5	103	103	115.5
	3	102	102.5	114.5	96.5	97.5	105.25	97.5	98	99.5	97.5	98	109.5



at the operator's ear were measured. Using a special attachment the microphone was mounted 16 cm behind the pipe of the exhaust outlet. The microphone was covered with a windscreen to protect it from emitted gases and impurities. IDLE and W.O.T. noise was measured while the ST4A scooptram remained stationary, and also under simulated working conditions (L.H.D.). IDLE and W.O.T. measurements were done simultaneously with the octave band analysis which has already been discussed.

Measured results are displayed in Appendix B, 1-6. To ensure better absolute and relative values at the exhaust outlet, all results were obtained by using the same instruments (Logger type = dB-301/16, Serial Numbers: 3428, 3146, 3425 and 3421). In the last two measurements, scooptram with filter 2 and scooptram with filter, muffler and fume diluter, the above mentioned instrument with Serial Number 3421 was used in order to maximize precision. All instruments were calibrated before and after completing the measurements. To characterize noise, 1 min averaging levels were deployed, and the following engine states were evaluated: IDLE, W.O.T. and working condition. In Appendix B, 1-6, the mean and standard deviation were calculated for each motor state. Results are sorted in Table 3. From these results it is clear that the ST4A scooptram with filter, muffler and fume diluter provides the best attenuation on both exhaust pipes. On the left side the attenuation is from 11.3 dBA to 15.3 dBA. At the operator's ear, attenuation is a lot less, from 1.9 dBA to 4.8 dBA. The fume diluter produces noise from 1.7 to 1.6 dBA more than when only filter 2 is installed. While the motor is in its work state, the noise level is the same with filter 2. The resulting confidence was evaluated using a t-distribution test. In Table 4 there are calculated value lengths of a 99% confidence interval in dBA. In only 3 cases is the length of the confidence interval longer. Two of the cases occur when filter 2 is on the right side of

Table 3 - A-weighted sound pressure levels (SPL_g) of the Wagner ST4A scooptram at left and right side, exhaust outlets and the operator's ear. Engine at IDLE, W.O.T. and Work states.

Condition of Test	Engine Status	Minutes	Noise in dBA							
			Scooptram						Operator (3)	
			Left Side (1)		Right Side (2)		Both Sides			
			Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Without Filter	Idle	33	102.76	0.61	101.86	0.86	101.91	1.13	86.24	1.25
	W.O.T.	28	119.93	1.46	116.93	1.7	118.43	2.26	102.64	1.73
	Work	31	116.58	1.18	112.29	1.04	114.44	2.43	100.94	1.18
With Filter-1	Idle	27	97.22	0.97	97.93	1.21	97.57	1.14	84.7	2.46
	W.O.T.	26	108.69	0.97	109.04	1.7	108.87	1.4	96.92	1.52
	Work	32	105.63	1.18	103.91	1.04	104.77	1.51	97.41	1.1
With Filter-2	Idle	14	97	-	96.64	0.5	96.82	0.39	82.64	2.71
	W.O.T.	11	109.91	0.83	110.09	1.64	110	1.27	95.18	0.4
	Work	28	106.54	1.14	104.43	1.62	105.46	1.75	96.14	0.36
With Filter Muffler and Fume Diluter	Idle	13	91.46	0.52	95	-	93.23	1.84	84.31	0.48
	W.O.T.	12	106.67	0.49	108	0.74	107.33	0.92	96.75	0.45
	Work	30	101.3	1.09	104.17	0.91	102.75	1.96	96.13	0.86

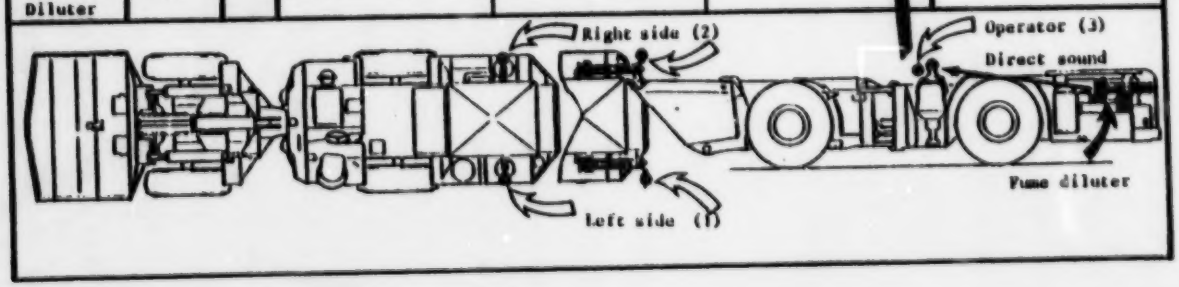
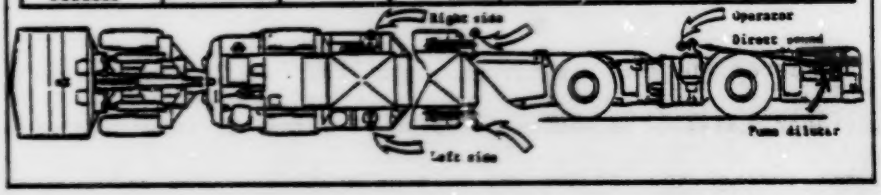


Table 4 - Results of the t-distribution test.

Condition of Test	Engine Status	Minutes	Length of 99% confidence interval in dBA			
			Scooptram			Operator
			Left Side	Right Side	Both Sides	
Without Filter	Idle	33	0.54	0.78	1.02	1.12
	W.O.T.	28	1.52	1.78	2.36	1.8
	Work	31	1.1	0.96	2.25	1.1
With Filter-1	Idle	21	1.04	1.3	1.22	2.6
	W.O.T.	26	1.06	1.86	1.53	1.65
	Work	32	1.08	0.95	1.37	1.0
With Filter-2	Idle	14	-	0.84	0.63	4.36
	W.O.T.	11	1.5	3.13	1.21	0.76
	Work	28	1.2	1.7	1.83	0.22
With Filter Muffler and Fume Diluter	Idle	13	0.88	-	3.12	0.26
	W.O.T.	12	0.88	1.3	1.65	0.8
	Work	30	1.1	0.92	1.97	0.32



the motor at W.O.T.; and one at the operator's ear at IDLE. Perhaps this is because the duration of observations was shorter or due to the operator moving his head. The third case is when the motor is equipped with filter, muffler and fume diluter on both sides of the scooptram. It has a confidence interval slightly greater than 3 dBA, which can be explained by uneven metal filling of filters or the small dimensions of resonant mufflers.

The range of tolerance limits for a Type 2 Sound Level Meter is from plus 3.5 dB or minus 4.0 dB in the low frequencies, to plus or minus 3.5 dBA at 8000 Hz. Sound level tolerance limits are widest at 4000 to 8000 Hz, and the noise level reading is greatly influenced by these limits, especially at the higher frequencies (Table 5).

In light of the foregoing, an arbitrary decision was made to use a ± 2 dBA limit on overall noise dosimeter accuracy (3). This gives another reason for a high degree of confidence in all the results presented in Table 3 and tested in Table 4. All lengths of 99% confidence intervals in dBA are under 4 dBA, except where there is 4.36 dBA at the operator's ear.

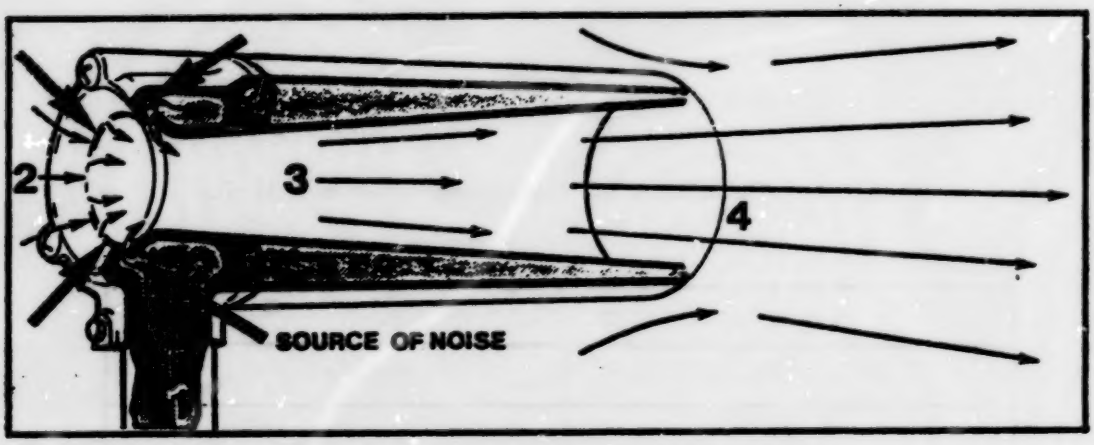
NOISE PROBLEMS OF FUME DILUTER

Completed analyses clearly show that the fume filter increases noise at the operator's seat. The source of noise is a radial connection which releases fumes through the annular gap to accelerate over the aerofoil surface (Fig. 3). Marked increases of noise occur at 1000 Hz and 2000 Hz (Appendix A, 4). Lower frequencies have no effect in increasing noise. This is proof that noise at the operator's set can be decreased by using a saucer-shaped deflector, with its concave surface pointed at the throat of the tube (Fig. 4).

Ideal deflector size and its distance from the throat of the fume diluter can be ascertained only through further experiments. Installed ECS

Table 5 - The effect of instrument tolerance limits

Sound Level Meter ANSI S1.4-1871, Type 2	
Frequency, Hz	A-Weighting dB
31.5	+3.5, -4.0
63	+3.0, -3.0
125	+2.5, -2.5
250	+2.5, -2.5
500	+2.0, -2.0
1000	+2.0, -2.0
2000	+3.0, -3.0
4000	+5.5, -4.5
8000	+6.5, -6.5



(1) Primary supply entry (3) Induced air mixes
(3) Secondary supply (4) High velocity air emitted

Fig. 3 - Fume diluter (4).

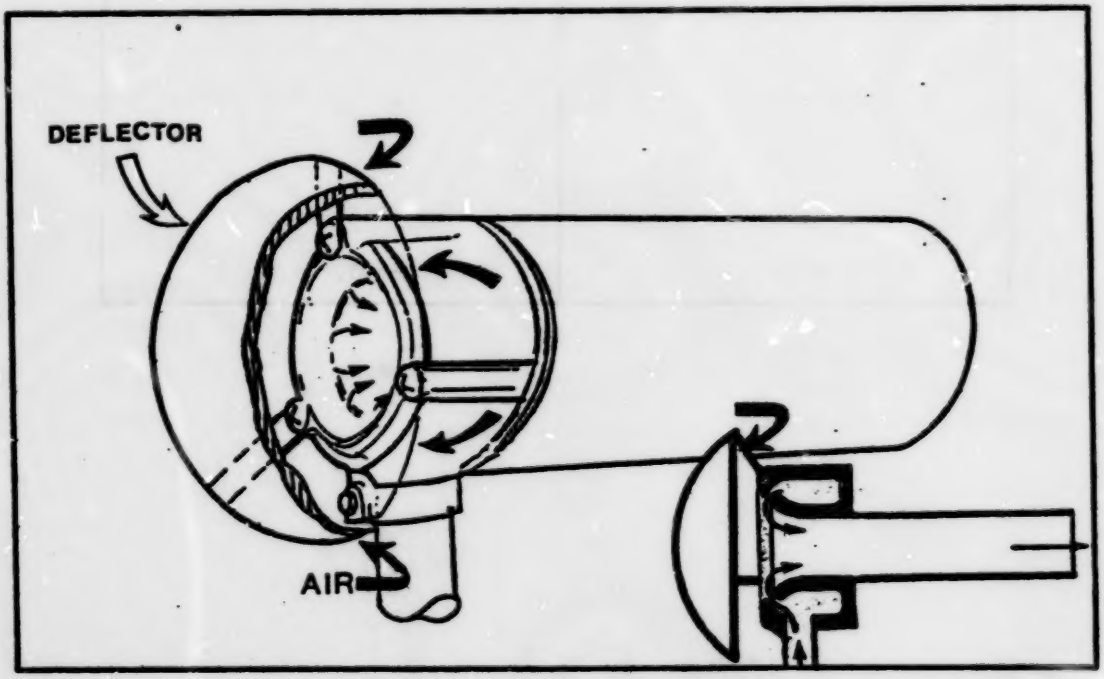


Fig. 4 - Deflector in fume diluter.

resonant mufflers should be further tested without fume diluters, as should fume diluters without the resonant mufflers. Should this demonstrate that the muffler is inefficient in tandem with the filter and fume diluter, more attention will have to be given to the fume diluter. Modifying the fume diluter and deploying it in tandem with the resonant muffler could make a good technical solution. Close approximations of the design chart have shown that new attempts can be made at decreasing noise in this system. Experimental work, using the design chart for lined duct or resonant mufflers will greatly reduce the theoretical work required for improved design (5).

CONCLUSION

This is the first study which concentrates exclusively on the noise of Load- Haul-Dump (LHD) vehicles emitted at the exhaust outlet under different engine states in relation to the operator's site. The study had two objectives:

1. to determine what noise levels the Wagner ST4A scooptram produces at the exhaust outlet and the levels of operator's exposure to this noise under four conditions:
   - scooptram without muffler or filter;
   - scooptram with small filter;
   - scooptram with large filter;
   - scooptram with large filter, muffler and fume diluter.
2. To recommend improvements or means for their control.

Measurement results demonstrate that the combination of filter, muffler and fume diluter provides maximum abatement of exhaust noise - around 8 dBA - for both sides of the outlet. The operator is exposed to a higher level of noise when a fume diluter is built into the entire system. This is understandable, since the fume diluter is a new source of noise, noise which

must be decreased. Studying this problem is fairly complex and demands lengthy experimentation. As a provisional measure a saucer-shaped deflector is recommended. This deflector must be mounted at the inlet of the fume diluter to protect the operator from the noise. After this experimental confirmation, this method is recommended for practical and permanent utilization.

These results and their evaluation show that:

1. The use of filters alone can reduce the noise level at the operator's ear at W.O.T. to within 5 dBA of the noise standard.
2. Fume diluters add noise because of their design and this noise can be reduced with further evaluation and initially with a noise deflector.
3. Noise, 1 m from the scooptram, is reduced by 11.7 dBA from exhaust treatment along, and will reduce the noise hazard for other personnel in the stope.

ACKNOWLEDGEMENTS

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REFERENCES

1. Patterson, W.H., Huggins, G.G. and Galaitsis, A.G., "Noise of diesel-powered underground mining equipment: impact, prediction and control"; U.S. Bureau of Mines Report No. 2979; March 21, 1975.

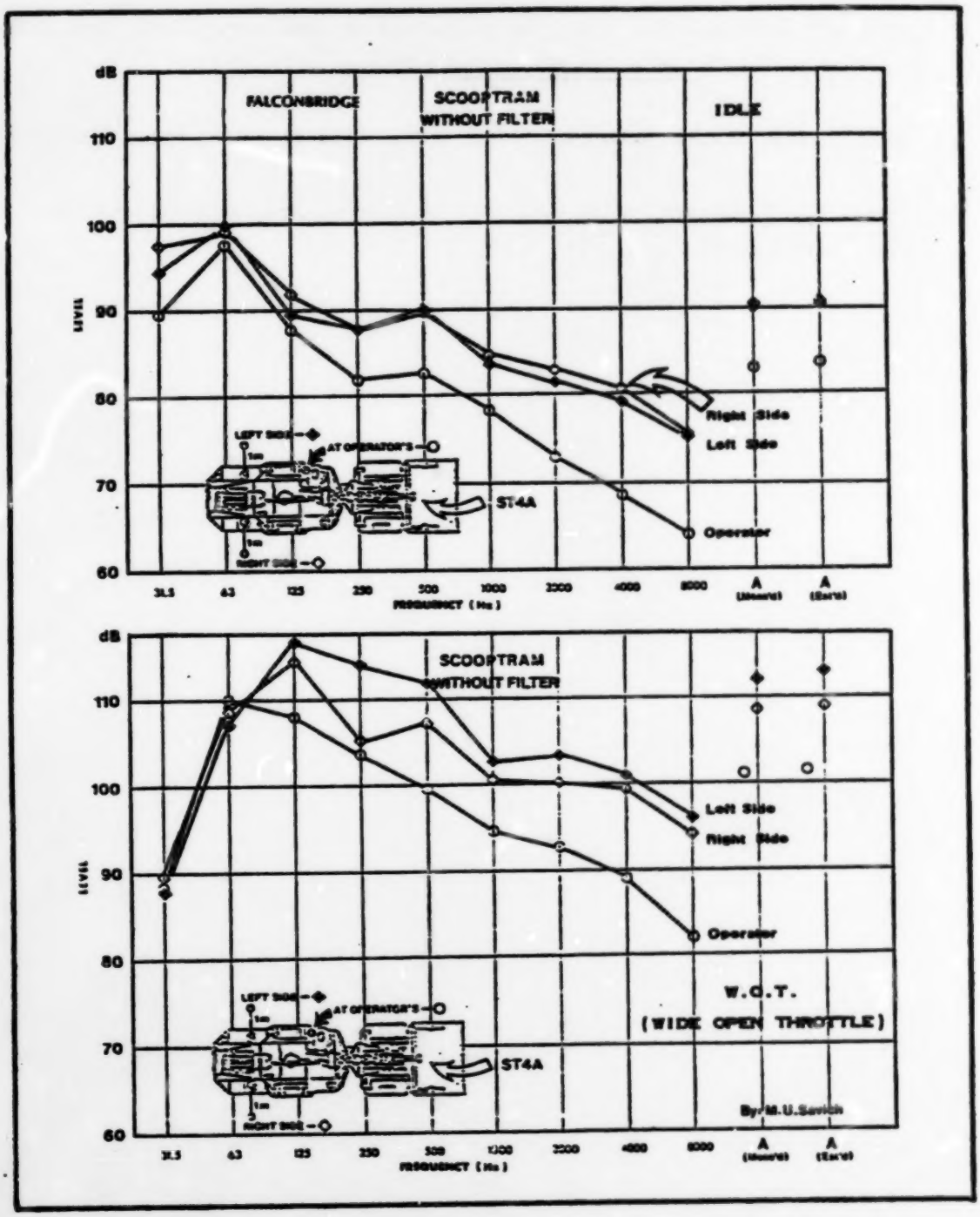
2. Bandopadhyad, S. and Ramani, R.V., "Computer-aided analysis of diesel exhaust dispersions in underground airways"; CIM Bulletin, vol 76, No. 858, October 1983.

3. Saks, H.K. and Lamonika, J.A., "An evaluation of some commercially available audio-dosimeters"; Proc. NOISEXPO Conf., Chicago, Ill, 1973.

4. Haskel Energy Systems Ltd., Sunderland, U.K.; data from 1980 sales literature.

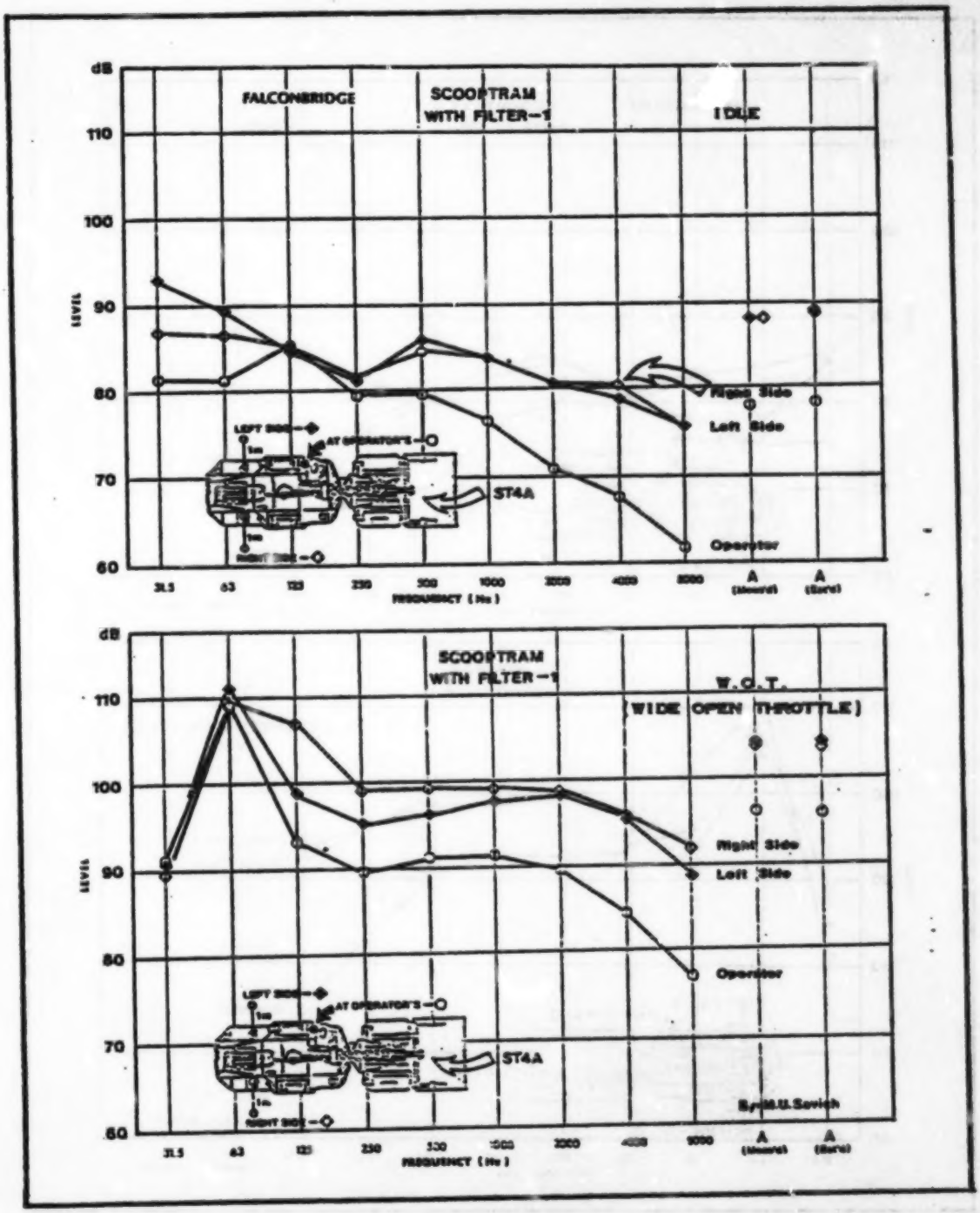
5. Fader, B., "Industrial noise control"; A Wiley-Interscience Publication, John Wiley & Sons, Inc., 1981.

Appendix A-1



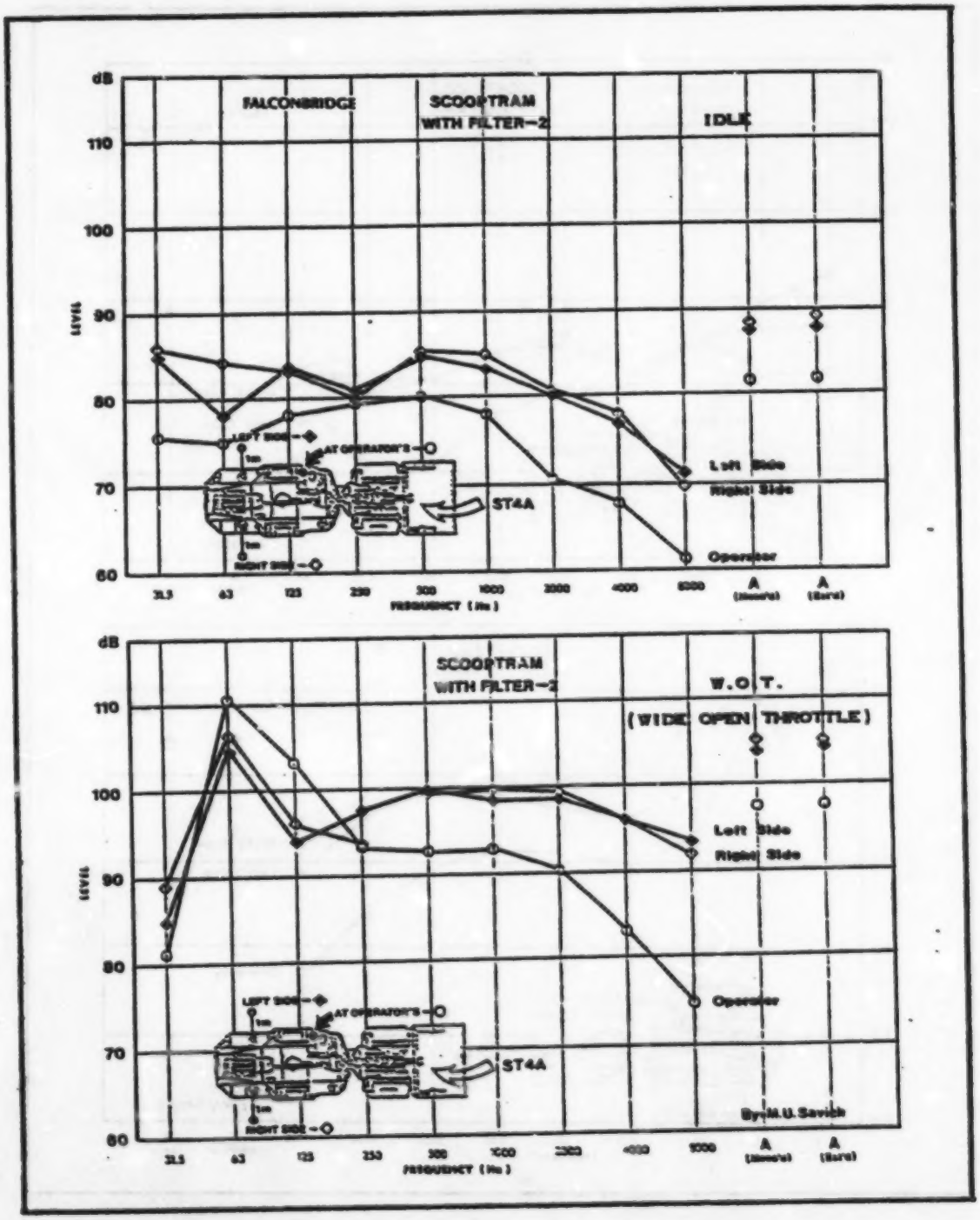
The noise spectrum in octave bands, produced by the ST4A scooptram without filter at engine states IDLE and W.O.T.

Appendix A-2



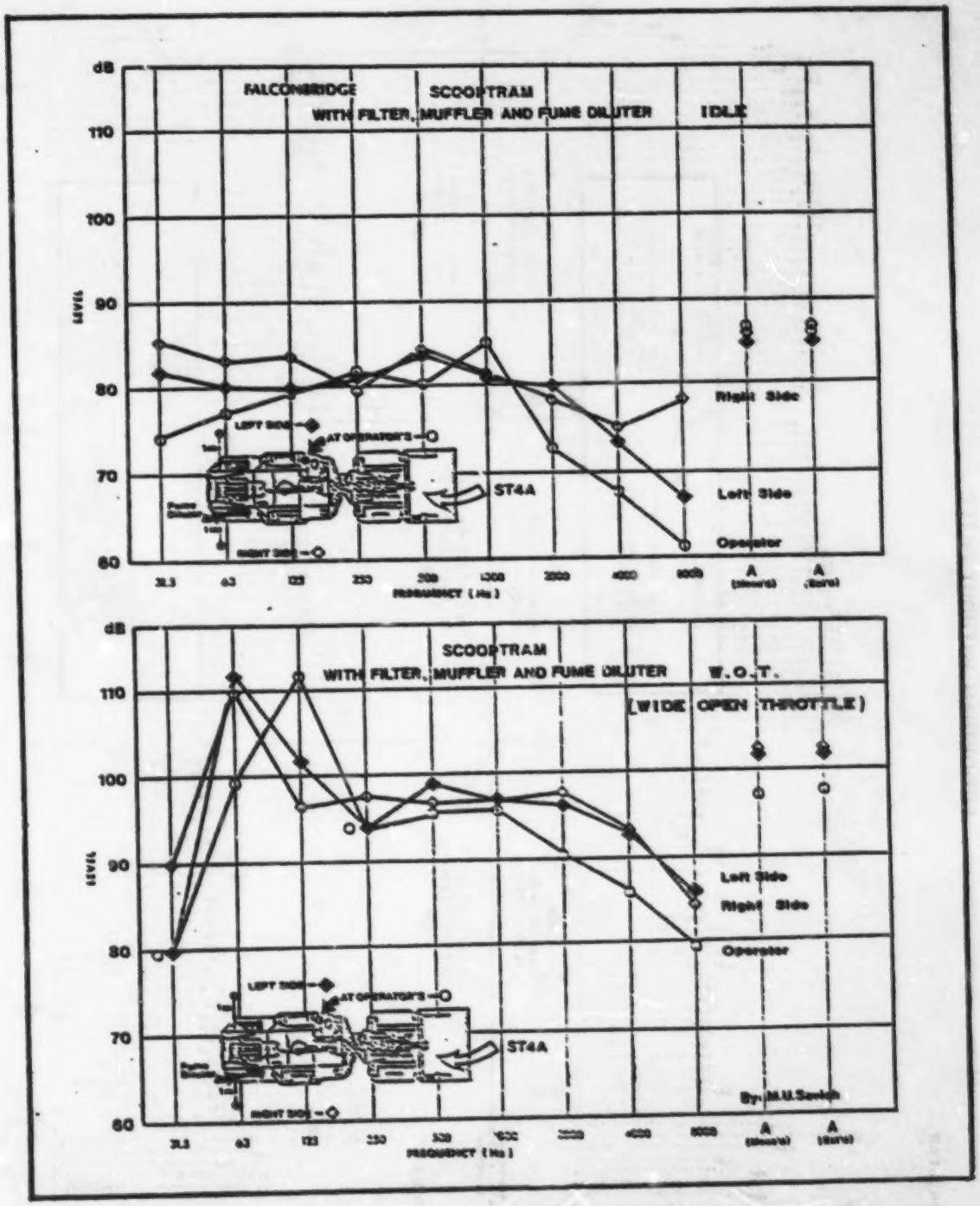
The noise spectrum in octave bands, produced by the ST4A scooptram with filter 1 at engine states IDLE and W.O.T.

Appendix A-3

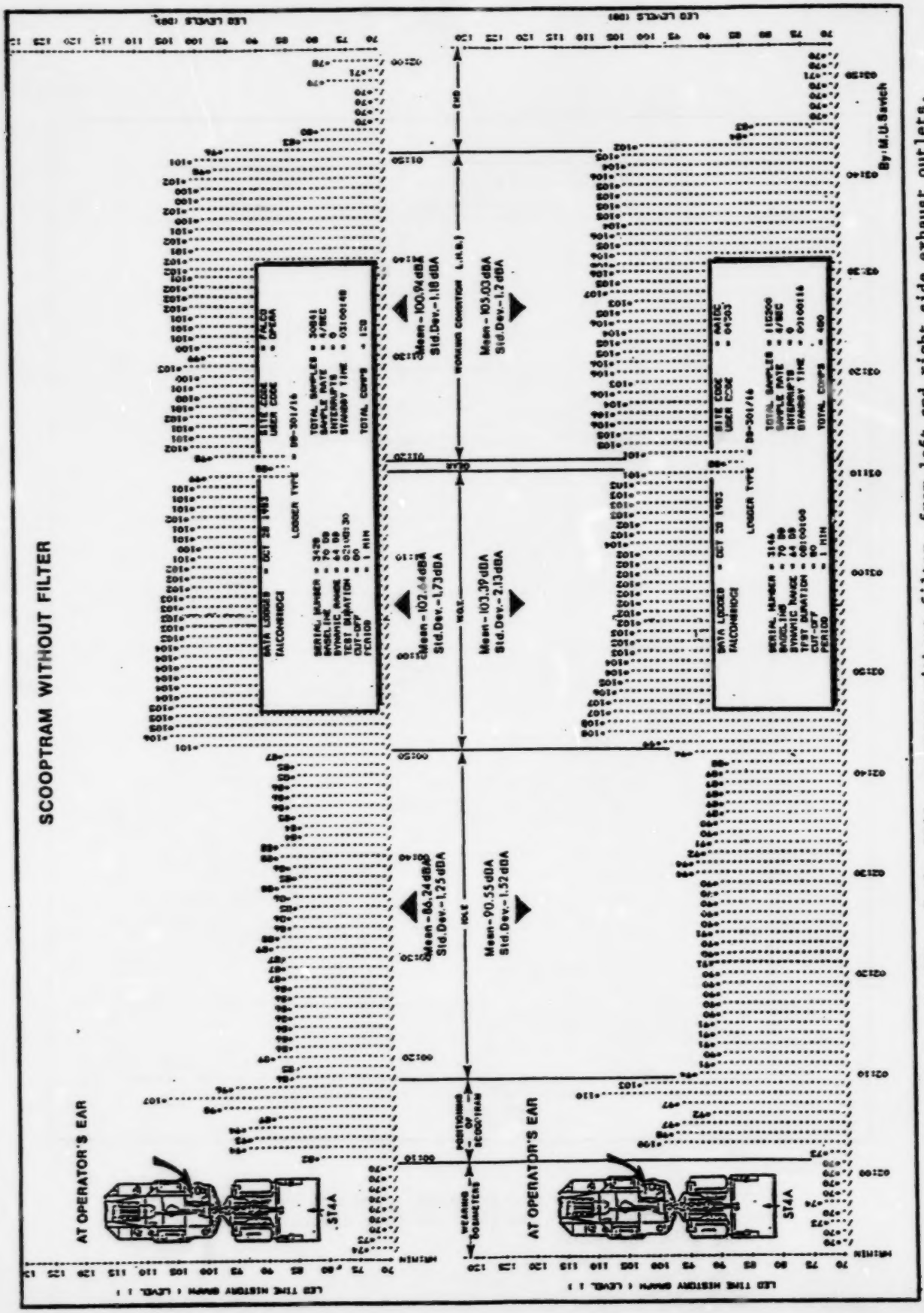


The noise spectrum in octave bands, produced by the ST4A scooptram with filter 2 at engine states IDLE and W.O.T.

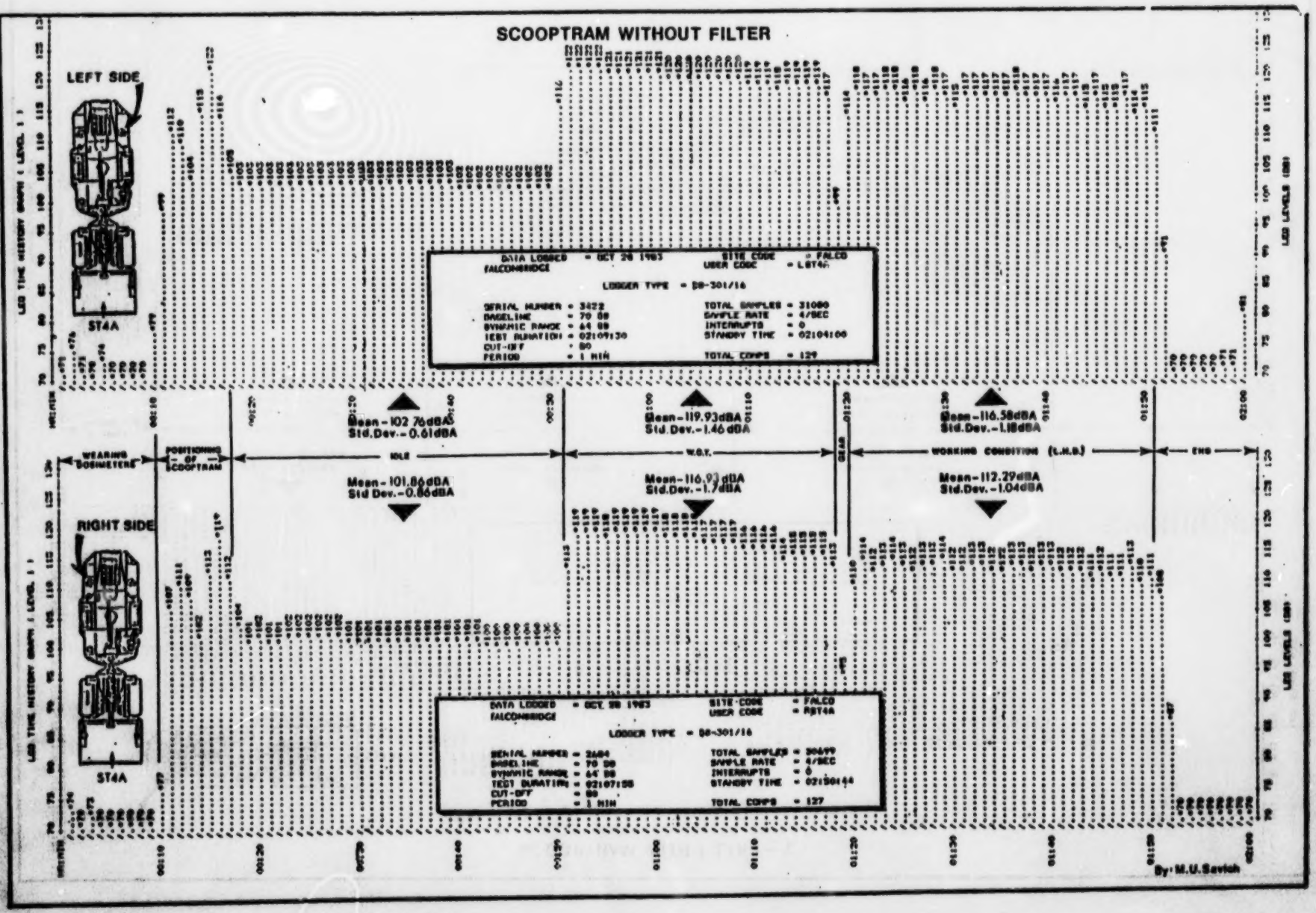
Appendix A-4



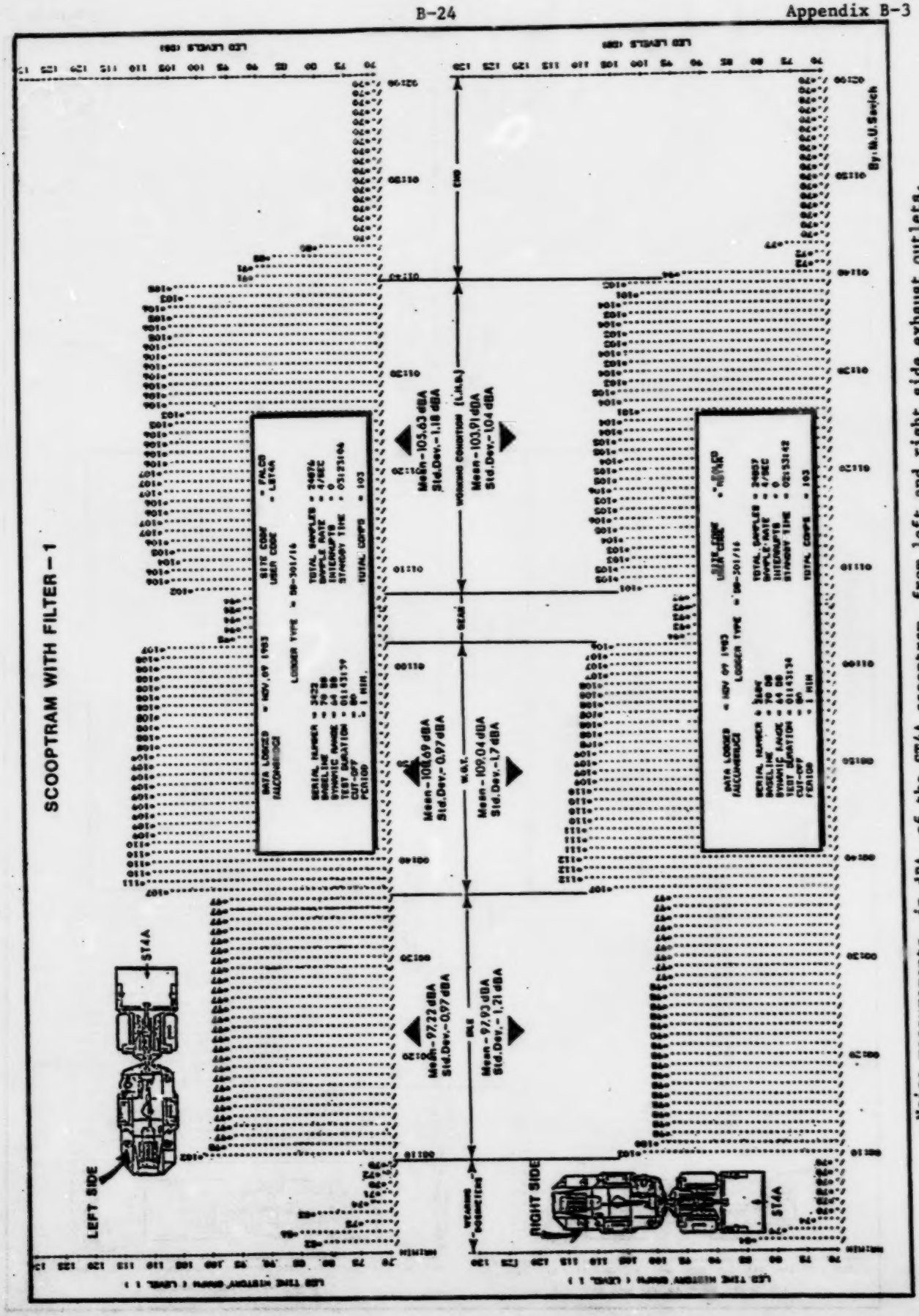
The noise spectrum in octave bands, produced by the ST4A scooptram with filter, muffler and fume diluter at engine states IDLE and W.O.T.



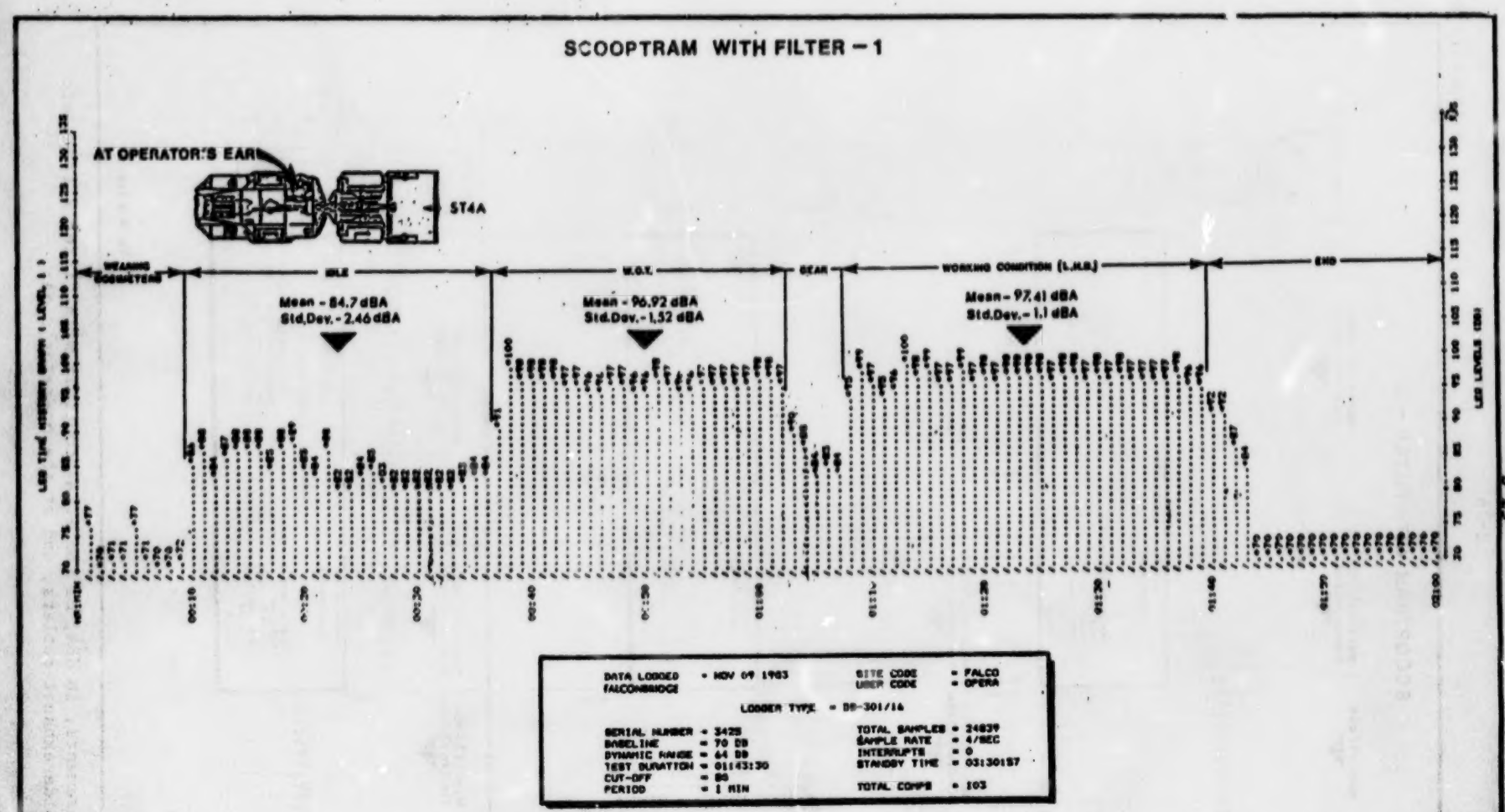
Noise measurements in dBA, of the ST4A scooptram without filter, from left and right side exhaust outlets.



Noise measurements, in dBA, of the ST4A scooptram at operator's ear. These measurements were made using two dosimeters.

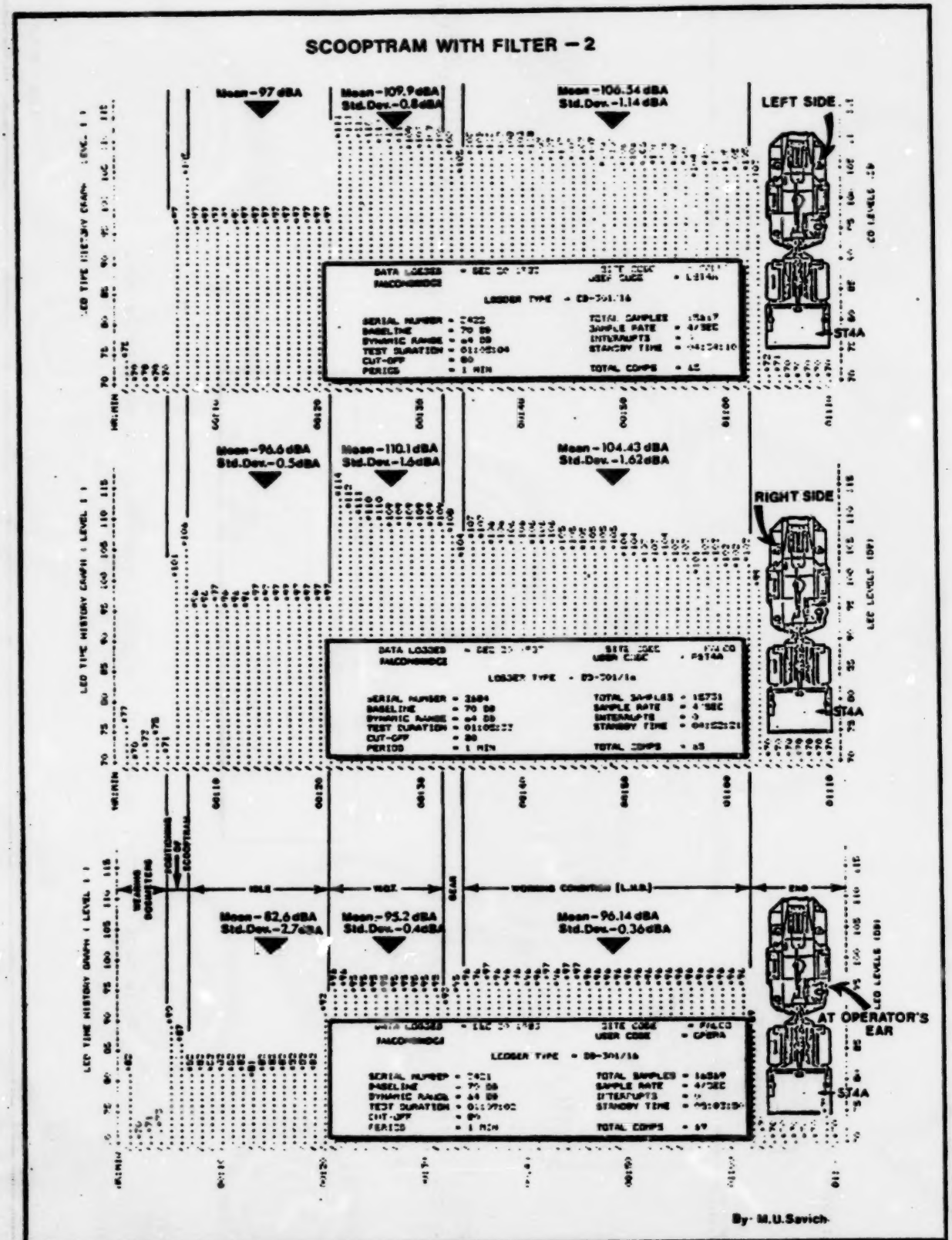


Noise measurements, in dBA, of the ST4A scooptram, from left and right side exhaust outlets.



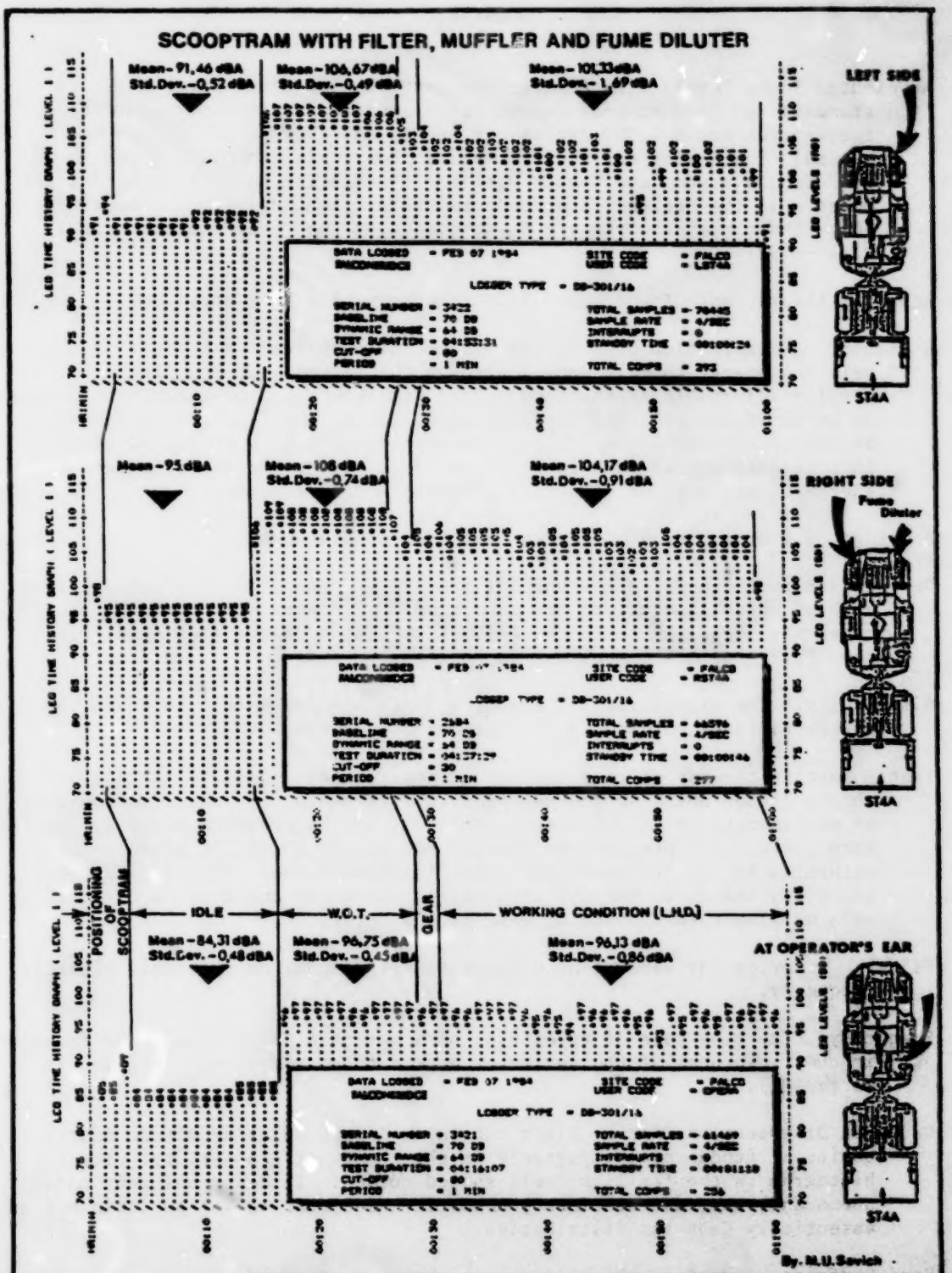
Noise measurements, in dBA, of the ST4A scooptram at the operator's ear.

Appendix B-5



Noise measurements, in dBA, of the ST4A scooptram with filter 2 from left and right side exhaust outlets, and at the operator's ear.

Appendix B-6



Noise measurements, in dBA, of the ST4A scooptram with filter, muffler and fume diluter from left and right side exhaust outlets, and at the operator's ear.

GLOSSARY

A-Weighted Sound Level: The A-weighting network of a sound level meter is a standardized frequency-dependent filter which discriminates against frequencies below 1,000 cycles per second and above 4,000 cycles per second. The A-weighted sound level is the single number that one would read from a sound level meter with the A-weighting network. The unit of measure is the decibel, and, to note the A-weighting, it is abbreviated dBA. The three networks are designated A, B and C, according to ANSI S1.4 - 1971.

Acoustic Absorption: The change of sound energy into some other form.

Analyzer: A combination of a filter system and a system for indicating the relative energy that is passed through the filter system. The filter is usually adjustable so that the signal applied to the filter can be measured in terms of the relative energy passed through the filter as a function of the adjustment of the filter response-vs-frequency characteristic. This measurement is usually interpreted as giving the distribution of energy of the applied signal as a function of frequency.

Damping: The dissipation of energy with time or distance.

Decibel (dB): A dimensionless unit of measure of the ratio of two quantities, each of which is equal to or proportional to power. If P_1 and P_2 are 10 times the logarithm to the base 10 of the ratio of two such quantities, then P_1/P_2 has the dimensions of decibels.

Directivity: The directivity of a source describes the extent to which the source radiates more sound in some directions than others.

Fast: Fast is the way of reading through intermittent noise to investigate what a steady noise source contributes. It means that the time constant of the instrument is 200 m/sec. That is, if the pressure abruptly changed from one dynamic pressure to another and stayed there 200 m/sec before returning to its original level, the instrument reported the difference in level, assuming that its response in the meter and driving circuit were no slower than anything else in the meter.

Filter: A device for separating components of a signal on the basis of their frequency.

Frequency: The time rate of repetition of a periodic phenomenon. The frequency is the reciprocal of the period of a pure tone. Frequency is given in Hertz (Hz).

Gaussian Distribution (Normal Distribution): A particular amplitude distribution of fundamental importance in the theory of probability. Its histogram is the familiar 'bell-shaped curve'. It describes many natural phenomena, and most stationary acoustic noise that is not periodic has an essentially Gaussian distribution.

Hard Surface: A surface which is a poor absorber of sound.

Histogram: Graph of an amplitude density distribution.

Idle Speed: The engine's low idle speed as specified by the manufacturer (see SAE J35+ and J1003*).

Impact: A single collision of one mass in motion with a second mass which may be either in motion or at rest.

Impact in Acoustic: See Peak.

Impulse: Impulse noise is supposed to represent what happened in the inter esting 35 m/sec. Also defined as a change of sound pressure of 40 dB or more within 0.5 sec. (European countries make use of this setting and write laws where it is important.)

Isolation: Isolation is a reduction in the capacity of a system to respond to an excitation, attained by the use of a resilient support.

Kilohertz (kHz): 1,000 Hz.

Level: In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified. Levels are always expressed in decibels (dB).

Mean: The mean is a value such that the sum of deviations of observations from it is zero; it is thus the sum of the observations divided by their number:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

where x_i is an observation or measurement, n the total number of observations, and $\bar{x}$ the mean.

Microphone: An electroacoustic transducer that responds to sound waves and delivers essentially equivalent electric waves.

N(newton): The base unit of force, $mkgs^{-2}$.

Noise: Any undesired sound or any erratic, intermittent, or statistically random oscillation.

Noise Level:

1. The level of noise, the type of which must be indicated by further modifier or context.

Note: The physical quantity measured (e.g., voltage), the reference quantity, the instrument used, and the bandwidth or other weighting

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+ SAE J35 - Diesel smoke measurement, procedure recommended practice.

* SAE J1003 - Diesel engine emission, measurement procedure - recommended practice.

characteristic must be indicated.

2. For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated.

Noise Reduction: The difference in decibels between the sound pressure level on either side of a boundary construction is defined as the noise reduction (NR). Noise reduction can also refer to the number of dB by which sound pressure levels are reduced in a single space or at a fixed location due to introduction of noise control treatments.

Octave: The frequency interval in Hz or cycles per second between two sounds having a frequency ratio of two.

Octave Band: A frequency range bounded by upper and lower frequency limits f_u and f_l, where $f_u = 2f_l$. Octave bands are usually specified by their geometric mean frequency called the band center frequencies. The standard octave bands covering the audible range are designated by the following centre frequencies: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 cycles per second (Hz).

Pa(pascal): The base unit of pressure ($Pa = N/m^2$).

Peak: Impact (or peak) is somewhat more understandable. The meter has a rise time of about 20 usec and drives the peak it found into an amplifier. The amplifier, in turn, drives a 'remember' circuit that tells you the peak is reached. Have more faith in 'peak' than in 'impulse'.

Pure Tone: Sound wave whose sound pressure at a point varies sinusoidally with time and is characterized by its singleness of pitch. The time interval for one complete cycle of the sinusoidal pressure variation is known as the period.

Reverberation:

1. The persistence of sound in an enclosed space, as a result of multiple reflections after the sound source has stopped.

2. The sound that persists in an enclosed space, as a result of repeated reflection or scattering, after the source of sound has stopped.

Note: The repeated reflections of residual sound in an enclosure can alternatively be described in terms of the transient behaviour of the modes of vibration of the medium bounded by the enclosure.

Reverberant Field: That part of the radiated sound field where the waves reflected from the boundaries of the enclosure are superimposed upon the incident field. The reverberant field may be called a diffuse field if a great many reflected wavetrains cross from all possible directions and the sound energy density is very nearly uniform throughout the field.

Sound Pressure: The total instantaneous pressure at a point in the presence of a sound wave minus the static pressure at that point.

Sound: A disturbance that propagates through an elastic material (air, water) at a speed characteristic of that medium. The physical quantities of most interest are the sound pressure and sound power.

Sound Pressure Level: SPL, in dB, is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to a reference pressure. (Standard reference is 20 $\mu N/m^2$ for airborne sound. Different reference pressures are sometimes used for underwater sound.)

$$SPL = 20 \log \frac{p}{0.0002 \ \mu bar} \ dB \text{ re } 20 \ \mu P$$

Spectrum: The spectrum of a function of time is a description of its resolution into components, each of different frequency and (usually) different amplitude and phase.

Standard Deviation: A numerical indication of the scatter of values of a variable around their mean (symbol σ). Specifically, it is the square root of the mean squared deviation, given by:

$$\sigma = \sqrt{\frac{\Sigma d^2}{n - 1}}$$

where d is the difference between the grand mean and an individual observation and n is the number of observations. In a normal distribution, a range of two standard deviations on each side of the mean will include 95.45 percent of all values, and three standard deviations on each side of the mean, 99.73 percent. When the standard deviation is determined from a sample of values and not from the parent population (which is frequently unknown), the denominator within the square root should be taken in n - 1, due to the fact that one degree of freedom out of the total n is used to estimate the mean value x.

T-test: The t distribution can be used in estimation even if $n \geq 30$, provided that the parent population is normally (or approximately normally) distributed.

Waveform: Instantaneous amplitude as a function of time.

Wavelength: The wavelength of a pure tone is the distance between analogous points on two successive waves. Wavelength (λ), frequency (f), and the speed of sound (c) are related by the expression $c = f\lambda$. In most practical situations the sound of interest is more aptly described as noise (random noise) than as a finite composite of pure tones.

Weighting: Prescribed frequency response provided in a sound-level meter.

W.O.T.: Wide open throttle.